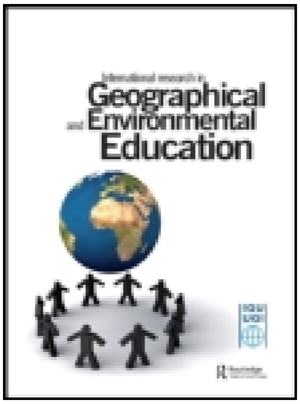

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GIS: The Technology is There but the Teaching is Yet to Catch Up

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The human population is increasingly applying destructive pressures on the natural environment to such an extent that the damage is becoming irreversible. We need to educate our young people in strategies of effective and sustainable environmental care, but to do this we need conservation science tools. The biological and mathematical disciplines alone seem inadequate to meet the conservation challenges, as are the computer tools (Breman, 2002). We need Geographic Information Systems (GIS) to reduce the multitude of information available into a manageable form. It seems that at some time in the past 15 to 20 Years, GIS has become the default solution for the integration of large multivariate data sets in almost all terrestrial spatial applications (Aronoff, 1991), and increasingly it is being developed for use in the marine sciences.

No longer are professionals turning to paper-based maps and data tables to analyse and interpret data. Instead a GIS application is used allowing not only visualisation of the data set, but also the facilitation of numerical and logical queries on a database, thereby providing an intuitive means to depict complex interrelationships among the data layers (Fonseca *et al.*, 2002). As a result, the past theoretical approaches from geography and ecology have become integrated with powerful databases whose statistical capabilities now allow the ecological sciences to become more predictive, rigorous, and directly integrated into all manner of social, political and resource decisions (Breman, 2002).

Explorers from ages past, from even a few decades ago, would wonder at the extraordinary insights made possible as layers of data are superimposed on precise renderings of terrain, and would readily understand how GIS has become indispensable to urban and regional planners, farmers, government, natural resource managers, policy makers, scientists of all sorts – to almost anyone who wants or needs to evaluate the scope of human activity, earth's natural processes, or their continuous interplay (Wright, 2002). GIS professionals are found in a variety of industries and government agencies, but very few are found in educational settings. Table 1 provides a sample of the industries, as identified by ESRI® (2005) that involve the applications of GIS in the workplace.

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Table 1 GIS in the workplace

Industry	*Specific examples*	
Business	Financial Services Retail and Commercial Business	Real Estate
Education	Universities K–12	Libraries Museums
Government	Economic Development Law Enforcement Sustainable Development Urban and Regional Planning	Elections Public Safety Federal
Natural Resources	Agriculture Archaeology Environmental Management Marine and Coast	Mining and Earth Science Conservation Forestry Pest Management
Utilities	Electric and Gas	Water and Wastewater
Health and Human Services	Health Data	Disease Mapping
Transportation	Impact on Utilisation	Travel Distance
Engineering and Surveying	Existing Conditions	Future Planning
Defence and Intelligence	National Security Rapid Response Systems	Strategy and Tactics
Communications	Media	Telecommunications

GIS maps share with traditional mapping, an approach that is graphic and cartographic as well as statistical. Koch (2005) claims the power of the GIS resides not only in the clarity of the visual representations of the data, but also in the manner in which the mapping process encourages our thinking about the relations between the data sets, and the factors that encourage or inhibit their mutual relations. In this, mapping stands not independent of, but in association with the other tools that assist in our understanding of both the nature of our world, and potential for its survival or demise. Data mapped onto the GIS surface is concerned with its relation to location, population characteristics, and environmental constraints.

GIS has transformed the way we describe and study the earth. We strive to understand the surface of the earth as the living environment of human populations and the forces of change that alter the earth's environments. The environment affects our health and well-being and we, through our activities, reshape the environment. Geographic Information Systems are computer-based systems for integrating and analysing spatial data, and therefore provide a digital lens for exploring the dynamic connections between people, their health and well-being, and changing physical and social environments (Cromley & McLafferty, 2002).

There is an obvious link, therefore, between the use of GIS and spatial thinking. Spatial thinking is a skill used in everyday life, the workplace, and in science to solve problems using concepts of space, visualisation and reasoning.

Table 2 School subjects

Natural Science	*Social Sciences*
• Biology • Biostatistics • Botany • Coastal Studies • Conservation • Ecology • Entomology • Environmental Science • Marine Science • Oceanography • Soil Science • Zoology	• Criminal Justice • Criminology • Demography • Economics • Ethnic Studies • Geography • Government • International Studies • Sociology • Travel and Tourism
Physical Sciences	*Natural Resources*
• Applied Physics • Astrogeology • Climatology • Computer Science • Geochemistry • Geology • Hydrology • Meteorology • Planetary Science • Seismology	• Fisheries • Forestry • Parks and Recreation • Water management • Wildlife Management

By visualising relationships of spatial structures in terms of locations, distances, directions, shapes and patterns, we can understand and analyse the properties of objects and relationships between objects. Spatial thinking can be taught to all students using appropriately designed tools, technologies, and suitably designed curricula. An initiative to integrate spatial thinking across mathematics, social studies and the sciences is needed. Starting with students in their first year of formal education would result in a generation of students who engage in spatial thinking to achieve success throughout their lives as citizens and members of the 21st century workforce (Committee on Support for Thinking Spatially, 2005). Given the need for lifelong learning skills in a technologically challenging world, all students can benefit from learning to think spatially, as it is an integrator and facilitator for problem solving across many subjects.

GIS tools for data management and spatial analysis can be put to use in a plethora of school subject areas. A selection of these is listed in Table 2. It should be noted that these subjects can be, and commonly are, taught to students of all ages. Why then is the trend that a number of Australian schools are integrating GIS into their geography curriculum, and very few Australian schools employ the use of GIS in science classes? This Australian trend appears to be opposite to that of the USA who use GIS more extensively in science classes than geography classes. Both countries tend to focus the usage on adolescents rather than on younger students. GIS implementation requires a significant commitment of time, money, and effort by the individuals and organisations adopting the technology. Whereas the adoption of GIS technology will be advocated by some

teachers, the commitment of these resources may not seem justified by other members of the school community whose activities are not primarily concerned with spatial analysis (Cromley & McLafferty, 2002).

The remainder of this paper relates to the implementation of GIS in schools. Initially, a rare instance where GIS was successfully accepted into the curriculum is described. This is followed by an exploration of the more common situation – no GIS usage in the schools. This exploration provides a summary of the factors involved in denying GIS its presence in the curriculum.

Successful Implementation of GIS in Schools

The integration of GIS was trialled at a Brisbane independent girls' school located in an Australian capital city. Initially this was done using *ArcView's* accompanying datasets in a Grade 8 Geography classroom. The implementation of GIS was made possible through a sponsorship programme involving ESRI Australia and the Queensland Department of Natural Resources.

The second author, then a teacher at the school, had previously reviewed the Geography curriculum of the school according to a set of pre-defined criteria. Most emphasis was given to (a) developing skills that students could use for lifelong learning; (b) developing skills in the application of intelligent spatial analytical software; and (c) enhancing independent and team-based learning skills. She then investigated other GIS applications in education to identify what software was being used in schools and selected the ESRI product *ArcView* for a range of reasons. ESRI Inc (USA) provided structured support to schools in the USA, and through the Adopt-A-School Programme had engaged numerous teachers and schools. In the USA, GIS was being used by students in Grades 4–12 for a variety of applications. The most pronounced applications were and continue to be in the sciences. The final decision to select *ArcView* was based on the proven ongoing support provided by the company to schools, the success of using *ArcView* in the classroom in the USA, recognition of the value of GIS in science school curriculum in the USA, the Adopt-A-School Programme and the relatively easy to understand software.

There was interest in pursuing the application of *ArcView* to the Australian learning context because of the demonstrated value of the software to learning and teaching in the USA. In addition, the review concluded that since the USA evidence had shown significant benefits of the links between schools and industry for students, then students in Australia should also be provided with skills that would open other vocational opportunities in the future.

It became increasingly evident that the students needed more than the datasets provided with *ArcView*. A number of government departments were approached and presented a strategic partnership concept so that datasets could be used specifically for school purposes. The result was a strategic sponsorship arrangement whereby the government sponsored the school with data from rural regions in the state. The sponsorship arrangements with other government organisations in other Australian states were also developed and implemented.

Within two years, students at the school were using *ArcView* in Grades 8, 10, 12 Geography. A number of students sought work experience in GIS-related fields and eventually completed tertiary studies with a focus on GIS. While the

students were learning how to use GIS, the second author also provided a series of workshops for teachers. It was her intention to share the experience in the anticipation that other teachers would develop an appreciation of the value of GIS in the school curriculum.

GIS in the school was proving to meet the criteria established by the second author. It became evident that teachers also needed to know how to use GIS. Integrating a GIS experience into the postgraduate education qualification was one way that preservice teachers could explore how GIS could be used in learning and teaching. In her role as a lecturer, the second author developed a GIS curriculum workshop for preservice teachers. This workshop enabled preservice teachers to explore the GIS applications to the school learning context. On graduation, several of the preservice teachers pursued the application of GIS to their school curriculum and to further tertiary studies.

Learnings from this experience for the Australian context include: the application of GIS in the school curriculum needs commitment from industry, schools, GIS software providers and the government. The success of the GIS program at the school was attributed to a number of inter-related reasons:

- the commitment of the teacher to exploring ways that students could be connected with their learning and the future by using an intelligent tool. In addition, ongoing professional learning to advance the skills of the teacher;
- support from the school leadership and the school community – success at this school would not have been possible had it not been for the Principal's support;
- support from the local tertiary institutions offering preservice teacher education programmes; and,
- support from government and industry.

Unsuccessful Implementation of GIS in Schools

Considering that this model for the use of GIS in Australian schools was developed over a decade ago, why is the tool not being used more widespread in Australia? Anecdotal evidence from other teachers throughout Australia indicates that there has been an ad hoc approach to the integration of GIS in the school curriculum. The most common response to the question: 'Why are you not using GIS?' is that teachers do not have the time to devote to developing their GIS skills, school leadership can't see the value, little timetable allocation to computers, insufficient technology resources and imbalanced technical support at schools.

A more serious attempt to ascertain why GIS is not widely used in schools was recently attempted. Teachers and school administrators were offered a free one-day mini-conference where the issues were discussed, hands-on sessions were available, and networking encouraged. Facilities available for the day restricted the participant number to 50; however, a waiting list quickly formed. A number of teachers registered on the day. Teachers and school administrators came from two Australian states, some driving up to four fours on the day to attend, another travelled to the venue location the night before and sought accommodation at his own expense. Obviously there is a school interest in including GIS into the curriculum.

Participants were asked why they were not using GIS, and what they thought they would need to make GIS education happen in their school. From the discussions on the day, three clear trends emerged: money, time and support. Teacher Professional Development (PD) was a common link between all three.

- Money was perceived to be needed to purchase software and teaching resources. The majority of teachers were unaware that most data needs to be purchased in Australia, unlike in the USA where it is freely available. Money was also going to be needed to pay for the PD and technical support in up-skilling the teachers. A major expense was seen to be the replacement of the teacher from his/her classes whilst undertaking the PD. In Australia this cost is several hundred dollars per day per teacher in major urban areas. In rural areas there may not be a replacement teacher available, so the classroom teacher is not able to undertake the PD as they are needed in the classroom.
- Time was an issue. Some teachers thought they would take considerable time in gaining confidence in using GIS in the classroom. This has a direct link with the time allocation for PD of the teacher. Also, accessing time in a computer laboratory with a class of students is perceived to be a major issue. Often it is not possible to gain entry to a computer laboratory as a computer class (computer programming, spreadsheeting, word processing) is timetabled into that room for the same lessons. Many teachers see GIS as an additional subject, and said they don't have time to introduce another subject into an already overcrowded curriculum. Work needs to be done with teachers and administrators to highlight GIS as an integration tool, not an additional workload.
- Support was seen to be paramount, but of a varying nature. First, teachers do not feel they have the technical abilities to set-up and maintain a GIS program in the school. There is a perception that it is very technical, and a 'techie person' is needed in each school to support their usage of the technology in their teaching. Second, there is support needed from the Administration/Leadership within the school to ensure funds and facilities are available for the development and sustainability of the GIS program in the school. There is also a need for District or Departmental support, to ensure all schools have access to GIS education. Some primary schools do not have computer laboratories, and students and teachers only have access to old hardware. Third, the teachers felt the need for resources in the form of printed units of work in order to get the programs started. Preferably these units would be relevant to the local area of the school; however this may not be possible due to the size and vast geographic distribution of Australian schools. Once teachers are more comfortable with using GIS as a teaching tool, they themselves can develop localised units. PD and support will also be needed to extend the skills of the teachers in the creation of data projects. Fourth, ongoing support for teachers was perceived as necessary. Once the teachers had begun using GIS, they felt they would need continuing support for trouble shooting, as well as for extending their skills and those of the students. It was requested this continuing support be both face-to-face as well as online. Finally, support from government departments was seen to be important. There was a general consensus that data should be free to schools.

Recently, one of the main software publishers in Australia realised that more school support was needed and appointed a classroom geography teacher to a 12 month contract. The result was an enhanced awareness of GIS strengths in learning and teaching across Australia. The following year saw the software publisher appoint another geography teacher to a longer term contract. The result was a consolidation of the earlier teacher's work as well as the development of extensive GIS curriculum support materials for teachers in Australia and the provision of ongoing professional development to schools. Obviously this is a move in the right direction, but it is not enough.

Funds need to be made available for the development and publishing of teaching materials. It is not important where the funds come from, but it would be logical if workplaces who rely on the usage of GIS by their employees were to foster the growth of a skilled generation. This can be achieved on a small scale through local businesses and local government authorities making data sets available, having students work on particular issues for them, and rewarding the schools with some funds or resources or work in kind. Larger companies and the multinationals could sponsor schools with data or equipment. At present, workplaces have to train their employees in GIS applications; however, through a sponsored education programme, new employees would be available to begin work in possession of the skills. Basic computer literacy is taken for granted in the majority of workplaces in today's society, and it should be the same with GIS skills.

Implications for GIS Education and Further Research

GIS has tremendous potential for being a tool that can connect students to post school opportunities not yet known. The technology is robust and well developed, used by many workplaces and integral in our nation's future well-being and defence. However, despite many isolated attempts by teachers to incorporate GIS into their curriculum, it has failed to make an impact in our schools. It seems minimal expenditure of funds is being made available for teacher professional development, for the purchasing of the software, and for the development of resources. Teachers are time poor, and need pre-designed resources to get the confidence to develop and use their own units.

Further research is required into how best to fund GIS education in terms of software and hardware provision. We also need to know what aspects of PD teachers need to do face to face, and what can be conducted more economically 'online'. The development of problem solving skills in the students and teachers alike is also requiring investigation. There is little point in pursuing this technology unless there are learning benefits. There is ample documentation of GIS success in geography, but little is known of the science applications.

Recommendations

Based on the authors' experiences, a number of recommendations for the future of geographical education in Australia (and perhaps elsewhere in the world) are presented:

1. Government needs to consider the integration of GIS in the social sciences and sciences curriculum programmes. This needs to be supported by funding at the national and state government levels.

2. Allocation of professional development funding (teacher release and for further studies) for the upskilling of teachers. The upskilling programme should be developed so that participating teachers are engaged in tertiary and industry level applications.
3. A partner-industry programme whereby industries using GIS sponsor teachers in a 'new work experience' programme that provides teachers with industry experience. This experience should be a part of the upskilling process.
4. Universities developing the upskilling programmes collaborate with partner-industries to ensure that industry specific needs are satisfied. The university based programmes should articulate to higher degree programmes.
5. GIS should be incorporated into targeted preservice teacher programmes in universities.
6. Partner-industries should provide a 'GIS Expert in Residence' programme to host schools to assist students and teachers with real-life industry examples of GIS applications.

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